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717 NORTH HARWOOD
DALLAS, TEXAS 75201
TELEPHONE 214 981 3300
FACSIMILE 214 981 3400

HONG KONG
LONDON
SHANGHAI
SINGAPORE
TOKYO

FOUNDED 1866

WRITER'S DIRECT NUMBER
(214) 981-3328

WRITER'S E-MAIL ADDRESS
pplap@sidley.com

July 13, 2000

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DERRICK GORDON

Name of Person Mailing Paper or Fee

Derrick Gordon

Signature

July 13, 2000

Date of Signature

Assistant Director
For Patents

Box PATENT APPLICATION
Washington, D.C. 20231

Re: New U.S. Patent Application
IMAGE DISPLAY APPARATUS
By: Ichiro KASAI, Yasushi TANIJIRI and Hideki NAGATA
Attorney Docket No. 15162/02080

Dear Sir:

Enclosed for filing are the following papers relating to an
IMAGE DISPLAY APPARATUS, Ichiro KASAI, Yasushi TANIJIRI and
Hideki NAGATA, inventors:

- (1) Specification;
- (2) Executed Declaration and Power of Attorney;
- (3) Drawings (7 sheets);
- (4) Certified Copy of the Priority Document;

07/13/00
1c845 U.S. PTO

1c714 U.S. PTO
09/615233
07/13/00

09/615233 at 07/13/00

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July 13, 2000

Page 2

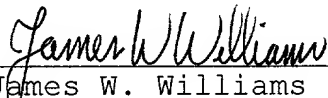
- (5) Information Disclosure Statement and PTO Form-1449,
with copy of cited reference;
- (6) Transmittal of PrintEFS Patent Application
Bibliographic Data;
- (7) Assignment of the invention to Minolta Co., Ltd.
with Recordation Form Cover Sheet;
- (8) Check in the amount of \$690.00 to cover the filing fee
of the application; and
- (9) Check in the amount of \$40.00 to cover the filing fee
of the Assignment.

In the event the attached checks in the amount of \$690.00 and \$40.00 are not received with this correspondence, are not sufficient, or in the event additional fees are due, please charge the required fees during the pendency of this application (other than issue fee) to Sidley & Austin's Deposit Account No. 18-1260. Please credit any overpayment to Sidley & Austin's Deposit Account No. 18-1260.

All correspondence is to be directed to the Applicants' attorney at the Dallas address listed above.

Respectfully submitted,

By:



James W. Williams

Registration No. 20,047

Attorney for Applicants

JWW/fis

Enclosures

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re

U.S. application: Ichiro KASAI, Yasushi TANIJIRI
and Hideki NAGATA

For: IMAGE DISPLAY APPARATUS

U.S. Serial No.: To Be Assigned

Filed: Concurrently

Group Art Unit: To Be Assigned

Examiner: To Be Assigned

Assistant Director

for Patents

Box Patent Application

Washington, D.C. 20231

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DATE OF DEPOSIT: JULY 13, 2000

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DERRICK GORDON

Name of Person Mailing Paper or Fee

Derrick Gordon

Signature

July 13, 2000

Date of Signature

TRANSMITTAL OF PrintEFS PATENT APPLICATION

BIBLIOGRAPHIC DATA

Submitted herewith is bibliographic data (2 pages) for the above-identified application, in the PrintEFS Version 1.0.1 program format.

Respectfully submitted,

By:

James W. Williams

James W. Williams

Registration No. 20,047

Attorney for Applicants

JWW/fis

SIDLEY & AUSTIN

717 North Harwood, Suite 3400

Dallas, Texas 75201-6507

(214) 981-3328 (direct)

(214) 981-3300 (main)

July 13, 2000

INVENTOR INFORMATION

Inventor One Given Name:: Ichiro
Family Name:: KASAI
Postal Address Line One:: Minolta Co., Ltd., Osaka Kokusai Bldg.,
Postal Address Line Two:: 3-13, 2-Chome, Azuchi-Machi, Chuo-Ku
City:: Osaka-Shi
State or Province:: Osaka
Country:: JAPAN
Postal or Zip Code:: 541-8556
City of Residence:: Kawachinagano-Shi
State or Province of Residence:: Osaka
Country of Residence:: JAPAN
Citizenship Country:: JAPAN
Inventor Two Given Name:: Yasushi
Family Name:: TANIJIRI
Postal Address Line One:: Minolta Co., Ltd., Osaka Kokusai Bldg.,
Postal Address Line Two:: 3-13, 2-Chome, Azuchi-Machi, Chuo-Ku
City:: Osaka-Shi
State or Province:: Osaka
Country:: JAPAN
Postal or Zip Code:: 541-8556
City of Residence:: Osakasayama-Shi
State or Province of Residence:: Osaka
Country of Residence:: JAPAN
Citizenship Country:: JAPAN
Inventor Three Given Name:: Hideki
Family Name:: NAGATA
Postal Address Line One:: Minolta Co., Ltd., Osaka Kokusai Bldg.,
Postal Address Line Two:: 3-13, 2-Chome, Azuchi-Machi, Chuo-Ku
City:: Osaka-shi
State or Province:: Osaka
Country:: JAPAN
Postal or Zip Code:: 541-8556
City of Residence:: Kobe-Shi
State or Province of Residence:: Hyogo-Ken
Country of Residence:: JAPAN
Citizenship Country:: JAPAN

CORRESPONDENCE INFORMATION

Name Line One:: James W. Williams
Name Line Two:: Sidley & Austin
Address Line One:: 717 North Harwood
Address Line Two:: Suite 3400
City:: Dallas
State or Province:: Texas
Country:: USA
Postal or Zip Code:: 75201-6507

Telephone One:: 214-981-3328
Fax One:: 214-981-3400
Electronic Mail One:: pplap@sidley.com
Telephone Two:: 214-981-3300
Electronic Mail Two:: jwillli09@sidley.com

APPLICATION INFORMATION

Title Line One:: IMAGE DISPLAY APPARATUS
Total Drawing Sheets:: 7
Formal Drawings?:: Yes
Application Type:: Utility
Docket Number:: 15162/02080
Secrecy Order in Parent Appl.?:: No

REPRESENTATIVE INFORMATION

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Registration Number Two:: 27189
Registration Number Three:: 37803
Registration Number Four:: 38425
Registration Number Five:: 29160
Registration Number Six:: 30067
Registration Number Seven:: 44196
Registration Number Eight:: 44234
Registration Number Nine:: 40313
Registration Number Ten:: 38595
Registration Number Eleven:: 41341
Registration Number Twelve:: 20047

PRIOR FOREIGN APPLICATIONS

Foreign Application One:: 11-199790
Filing Date:: 07-14-1999
Country:: JAPAN
Priority Claimed:: Yes

Source:: PrintEFS Version 1.0.1

IMAGE DISPLAY APPARATUS

This application is based on application No. H11-199790
filed in Japan on July 14, 1999, the entire contents of which are
5 hereby incorporated by reference.

BACKGROUND OF THE INVENTION

Field of the Invention

The present invention relates to a head-mounted image
5 display apparatus.

Description of the Prior Art

Conventional methods of obtaining high realism in an image
display apparatus that directs image light based on a displayed
image to the user's pupil include a method in which a displayed
image is projected onto the user's pupil as a virtual image
without an intermediate image being formed and a method in which
a displayed image is projected onto a screen and the user views
the image. These methods are advantageous in that a wide viewing
15 angle and a large pupil diameter are comparatively easily
obtained and high realism is obtained.

However, in the method in which a virtual image is projected
onto the user's eye without an intermediate image being formed,
a multiplicity of large-diameter lens elements are necessary to
20 achieve a wide viewing angle and a large pupil diameter, which
increases the cost of the optical system and the weight. On the
other hand, the method in which an image is projected onto a
screen and the user views the image is advantageous in that a

large pupil diameter can be achieved by diffusion by the screen and that the projection optical system can be made compact. Fig. 7 schematically shows the structure of the optical system of a conventional head-mounted image display apparatus based on this method.

An image display element 53 is illuminated by a lighting source 52, and the image light based on the image display exits from a projection optical system 54. The image light is reflected at a half mirror 51 and projected onto a reflective screen 56 to form an image. The reflected light from the screen 56 is transmitted by the half mirror 51 and supplied to the user's pupil EP. By this light, the user views the image on the screen 56.

However, in the conventional image display apparatus using a screen, the screen is fixed in front of the user. That is, since the screen is disposed away from the head, the overall mass moment of the apparatus imposed on the user's head is great, so that the load on the user when he or she wears the apparatus on his or her head is heavy.

SUMMARY OF THE INVENTION

An object of the present invention is to reduce the load on the user's head in a head-mounted image display apparatus using a screen.

To achieve the above-mentioned object, a head-mounted image display apparatus according to the present invention is provided with: an image display element; a projection optical system that projects an image displayed by the image display element; a

screen onto which the image is projected by the projection optical system; and a combiner disposed between the projection optical system and the screen. The combiner transmits the image light from the projection optical system and directs it to the screen, and reflects the image light reflected at the screen.

In the above-described structure, since the image light from the screen is directed to the user's pupil by being reflected at the combiner, the screen can be disposed close to the user's head. With this disposition, the overall mass moment of the apparatus imposed on the head is reduced.

It is desirable for the combiner to transmit external light and direct it to the user's pupil together with the image light. With this structure, an external image can be viewed together with the displayed image.

It is desirable for the image display apparatus to be put on the head through a head-mounted member, and for the screen to be integrated with the head-mounted member above or below the user's pupil. With this structure, the image display apparatus is easily constructed and the load on the user's head is further reduced.

Moreover, the image display apparatus may have a structure in which an eyepiece optical system is disposed between the combiner and the user's pupil and the user views the image projected onto the screen so as to be enlarged through the eyepiece optical system. In this structure, since the image projected onto the screen is viewed being enlarged, a wide viewing angle can be obtained or the size of the screen can be reduced. Moreover, the user's diopter can be controlled, which

enables excellent image viewing.

In the structure in which the eyepiece optical system is disposed, an optical element where the composite optical power of the optical element and the eyepiece optical system is substantially zero may be disposed on the external side of the combiner with respect to the eyepiece optical system. In this case, since the optical power to which the external light is subjected before reaching the user's pupil is substantially zero even though the eyepiece optical system is provided, excellent external image viewing can be performed.

Further, the image display apparatus may have a plurality of units each including the image display element and the projection optical system, so that images corresponding to the user's left and right pupils are formed on the screen. In this structure, by providing parallax between the left and right images, three-dimensional images can be viewed.

It is desirable for the screen used in the above-described structures to have a retroreflection characteristic. The retroreflection characteristic enables most of the light made incident on the screen to be incident on the user's pupil, so that bright images can be viewed.

BRIEF DESCRIPTION OF THE DRAWINGS

This and other objects and features of this invention will become clear from the following description, taken in conjunction with the preferred embodiments with reference to the accompanying drawings in which:

Fig. 1 shows the structure of an optical system of an image

display apparatus according to a first embodiment;

Fig. 2 shows a concrete structure of a head-mounted image display apparatus using the optical system of Fig. 1;

Fig. 3 shows a concrete structure of another head-mounted image display apparatus using the optical system of Fig. 1;

Fig. 4 shows the structure of an optical system of an image display apparatus according to a second embodiment;

Fig. 5 shows the structure of an optical system of an image display apparatus according to a third embodiment;

Fig. 6 shows the structure of an optical system of an image display apparatus according to a fourth embodiment; and

Fig. 7 shows the structure of the optical system of the conventional head-mounted image display apparatus.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

Hereinafter, embodiments of the present invention will be described with reference to the drawings.

<First Embodiment>

Fig. 1 shows the structure of an image display optical system of a head-mounted image display apparatus according to this embodiment. This optical system comprises a half mirror 1 situated in front of the user's pupil, a diffuse-reflective screen 6 disposed above the half mirror 1, and a projection unit 5 including a projection optical system 4, an image display element 3 and a lighting source 2 disposed below the half mirror 1. In this optical system, the distances from the user's pupil and the exit pupil of the projection optical system 4 to the half mirror 1 are substantially the same.

1 The image display element 3 is illuminated by the lighting
source 2, and the image light based on the image display exits
from the projection optical system 4. The image light is
transmitted by the half mirror 1 and projected onto the reflec-
5 tive screen 6 to form an enlarged image. The reflected light
from the screen 6 is reflected at the half mirror 1 and supplied
to the user's pupil EP. By this light, the user views the image
on the screen 6.

As described above, in this embodiment, the half mirror 1 is
10 used as a combiner, and the half mirror 1 transmits the light
from the projection unit 5 and directs it to the screen 6, and
reflects the light from the screen 6 and directs it to the user's
pupil EP. Moreover, the half mirror 1 transmits external light
LB and directs it to the user's pupil EP together with the image
15 light. Consequently, by the light from the half mirror 1, the
user can view an external image being superimposed on the image
on the screen 6.

A polarization separation surface may be provided instead of
the half mirror 1. In this case, by using it in combination with
20 a polarizing plate, the same working as that obtained through the
use of the half mirror 1 can be obtained. When a polarization
separation surface is used, since total transmission and total
reflection can be achieved by making incident the polarized light
responsive to the characteristic of the polarization separation
25 surface, the light quantity loss of the image light can be
reduced.

Fig. 2 shows a concrete structure of a head-mounted image
display apparatus using the image display optical system. In

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this apparatus, the image display optical system shown in Fig. 1 is provided in a viewing member 8, and the viewing member 8 is held by a helmet-type head-mounted member 7 through a rotating hinge 9. The viewing member 8 is retractable in the direction of the arrow A from a viewing condition shown by the solid line by the rotating hinge 9, and is in the condition shown by the dotted line when retracted. In the retracted condition, there is nothing to obstruct the user's view.

10 The head-mounted member 7 has earpieces 7a. The earpieces 7a each include a non-illustrated speaker so that sound based on externally transmitted sound signals is supplied to the user.

15 In the viewing condition of the viewing member 8, the screen 6 is disposed so as to extend forward from a neighborhood of the user's forehead and the projection unit 5 is disposed in the vicinity of the user's mouth, so that the mass moment imposed on the user's head by the viewing member 8 is small. Consequently, even if the user continues image viewing for a long time, the load on the user is light and the user does not easily get fatigued.

20 Fig. 3 shows a concrete structure of a head-mounted image display apparatus using the image display optical system which structure is different from that of Fig. 2. In this apparatus, the image display optical system shown in Fig. 1 is integrated with the head-mounted member 7. The head-mounted member 7 has a helmet configuration of which upper and lower parts protrude forward from the side of the user. The visor-like upper protruding part has the screen 6, and the projection unit 5 is provided in the lower protruding part. The head-mounted member

25

7 has earpieces 7a similar to those of Fig. 2.

In the image display apparatus shown in Fig. 3, because of the integration of the image display optical system and the head-mounted member 7, the mass moment imposed on the user's head is further reduced.

<Second Embodiment>

Fig. 4 shows the structure of an image display optical system of a head-mounted image display apparatus according to this embodiment. The structure of this optical system is similar to that of the optical system of the first embodiment except that an eyepiece optical system 10 is disposed between the half mirror 1 and the user's pupil EP. By interposing the eyepiece optical system 10, the user can view an enlargement of the image projected onto the screen 6, so that a wide viewing angle is achieved. Moreover, the image viewing distance (diopter) can be adjusted, which enables more natural image viewing.

<Third Embodiment>

Fig. 5 shows the structure of an image display optical system of a head-mounted image display apparatus according to this embodiment. In this optical system, an optical element 11 is further provided in the optical system of the second embodiment. The optical element 11 is disposed on the external side of the half mirror 1 with respect to the eyepiece optical system 10, and has an optical power which is substantially zero when joined with the optical power of the eyepiece optical system 10.

In this optical system, since external images are viewed through the eyepiece optical system 10 and the optical element 11, natural external images can be viewed.

<Fourth Embodiment>

Fig. 6 is a front view showing the structure of an image display optical system of a head-mounted image display apparatus according to this embodiment. This embodiment is different from the first embodiment only in that two projection units are provided in correspondence with the left and right eyes. By the projection light exiting from a projection unit 5L for the left eye, an image for the left eye is formed on the screen 6. The user's left eye EL views this image. By the projection light exiting from a projection unit 5R for the right eye, an image for the right eye is formed on the screen 6. The user's right eye ER views this image.

In this structure, three-dimensional images can be displayed by providing parallax between the left and right images.

It is desirable for the screen 6 of the optical systems of the first to the fourth embodiments to have a retroreflection characteristic. According to the retroreflection characteristic, the image light exiting from the exit pupil of the projection optical system can be efficiently made incident on the user's pupil, so that brighter images can be viewed. In the fourth embodiment, by providing the retroreflection characteristic, the left and right luminous fluxes from the screen can be separated. This reduces crosstalk between the left and right images so that more excellent three-dimensional images can be viewed.

While in the above-described embodiments, the projection unit is disposed below the half mirror 1 and the screen is disposed above the half mirror 1, they may be disposed in the opposite positions because similar effects are obtained when they

are disposed in the opposite positions.

While the screen is concave to the side of the projection optical system, the configuration of the screen is not limited thereto; for example, the screen may be flat. However, when the screen is concave with the exit pupil of the projection optical system substantially as the center, since diffusibility is uniformly obtained with respect to the direction of incidence, the diffusibility is uniform also on the user's pupil, so that uniform brightness across the angle of view is easily obtained.

In the case where the screen has the retroreflection characteristic, since the retroreflection efficiency decreases when the angle of incidence on the screen is large, it is desirable for the angle of incidence not to largely vary according to the angle of view. The concave shape is effective also in this respect.

Obviously, many modifications and variations of the present invention are possible in light of the above teachings. It is therefore to be understood that within the scope of the appended claims, the invention may be practiced other than as specifically described.

What is claimed is:

1. A head-mounted image display apparatus comprising:
an image display element;

a projection optical system that projects an image displayed
5 by said image display element;

a screen onto which the image is projected by said projec-
tion optical system; and

a combiner disposed between said projection optical system
and said screen,

10 wherein said combiner transmits image light from said
projection optical system and directs it to said screen, and
reflects the image light reflected at the screen.

2. A head-mounted image display apparatus as claimed in
15 claim 1,

wherein said combiner further transmits external light.

3. A head-mounted image display apparatus as claimed in
claim 1,

20 wherein said screen is disposed above or below a user's
pupil.

4. A head-mounted image display apparatus as claimed in
claim 1, further comprising an eyepiece optical system disposed
25 between said combiner and the user,

wherein said eyepiece optical system enlarges the image
projected onto said screen.

5. A head-mounted image display apparatus as claimed in claim 4, further comprising an optical element disposed on an external side of said combiner with respect to said eyepiece optical system.

6. A head-mounted image display apparatus as claimed in claim 5,

wherein a composite optical power of said eyepiece optical system and said optical element is substantially zero.

7. A head-mounted image display apparatus as claimed in claim 1,

wherein said image display apparatus has a plurality of units each including said image display element and said projection optical system.

8. A head-mounted image display apparatus as claimed in claim 7,

wherein said units form images corresponding to the user's left and right pupils.

9. A head-mounted image display apparatus as claimed in claim 1,

wherein said screen has a retroreflection characteristic.

10. A head-mounted image display apparatus as claimed in claim 1,

wherein said combiner is a half mirror or a polarization

separation member.

11. A head-mounted image display apparatus comprising:
an image display element;

5 a projection optical system that projects an image displayed
by said image display element;

a screen onto which the image is projected by said projec-
tion optical system; and

10 a combiner that reflects image light reflected at said
screen, and transmits external light.

12. A head-mounted image display apparatus as claimed in
claim 11,

5 wherein said combiner further transmits image light from
said projection optical system and directs it to said screen.

Variable	Mean	SD	Min	Max
Age	34.2	10.5	18	65
Gender	0.5	0.5	0	1
Marital Status	0.6	0.5	0	1
Education	12.5	1.5	9	16
Income	3500	1500	1000	10000
Health Status	0.7	0.5	0	1
Exercise Frequency	2.5	1.5	0	5
Stress Level	4.5	1.5	1	7
Sleep Quality	3.5	1.5	1	7
Dietary Habits	2.5	1.5	0	5
Work-Life Balance	3.5	1.5	1	7
Family Support	4.5	1.5	1	7
Community Involvement	2.5	1.5	0	5
Overall Well-being	4.5	1.5	1	7

5

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FIG.1

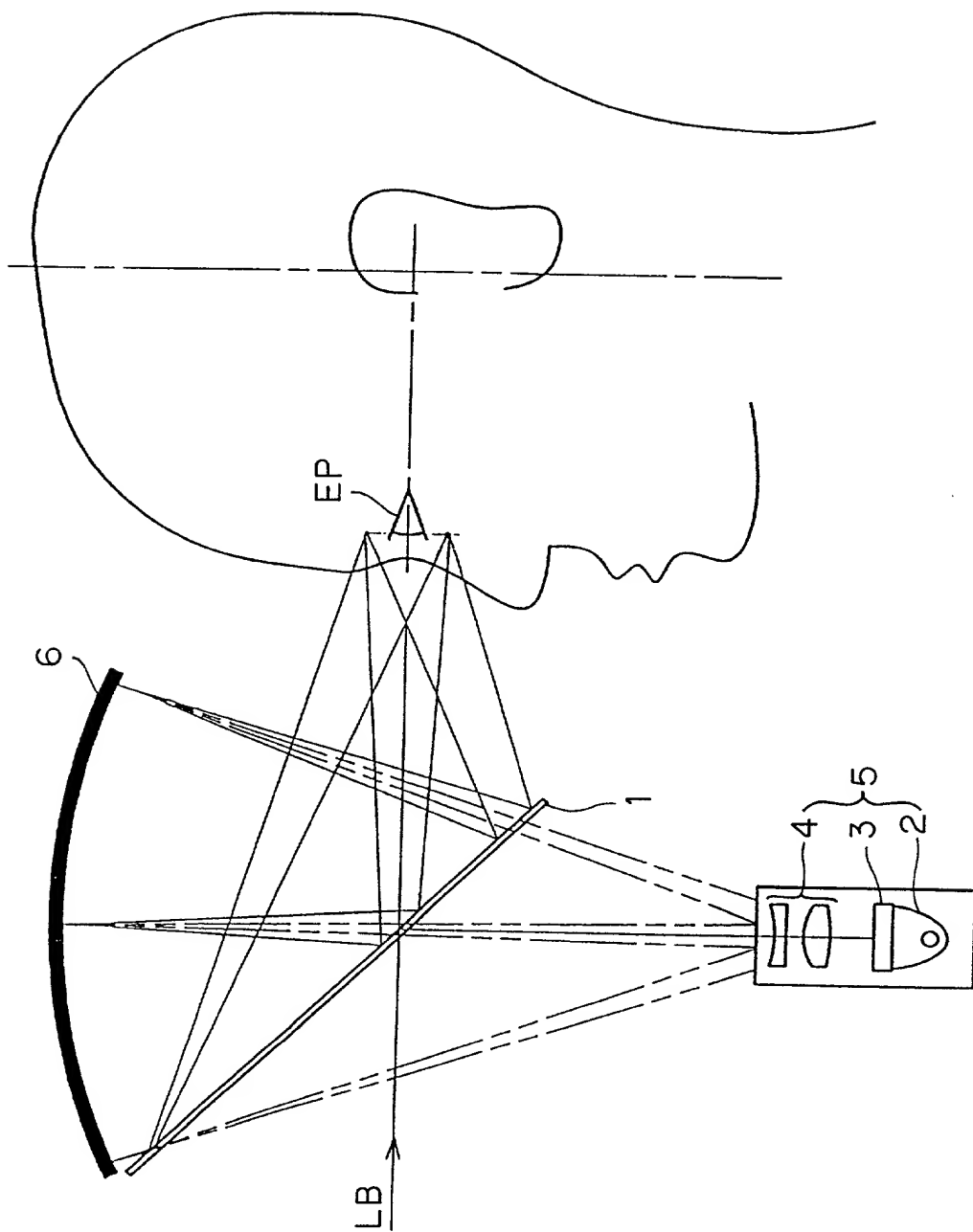


FIG. 2

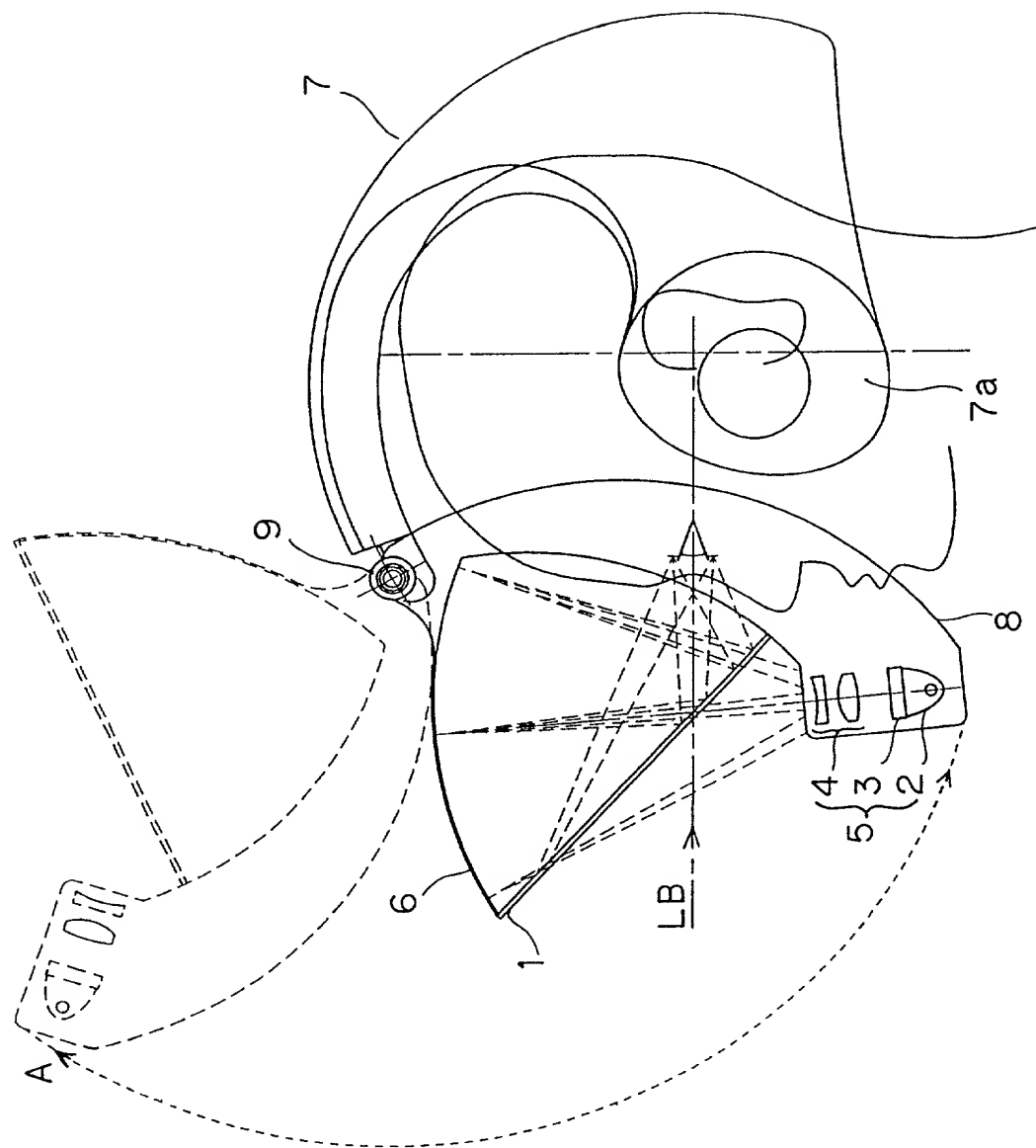


FIG. 4

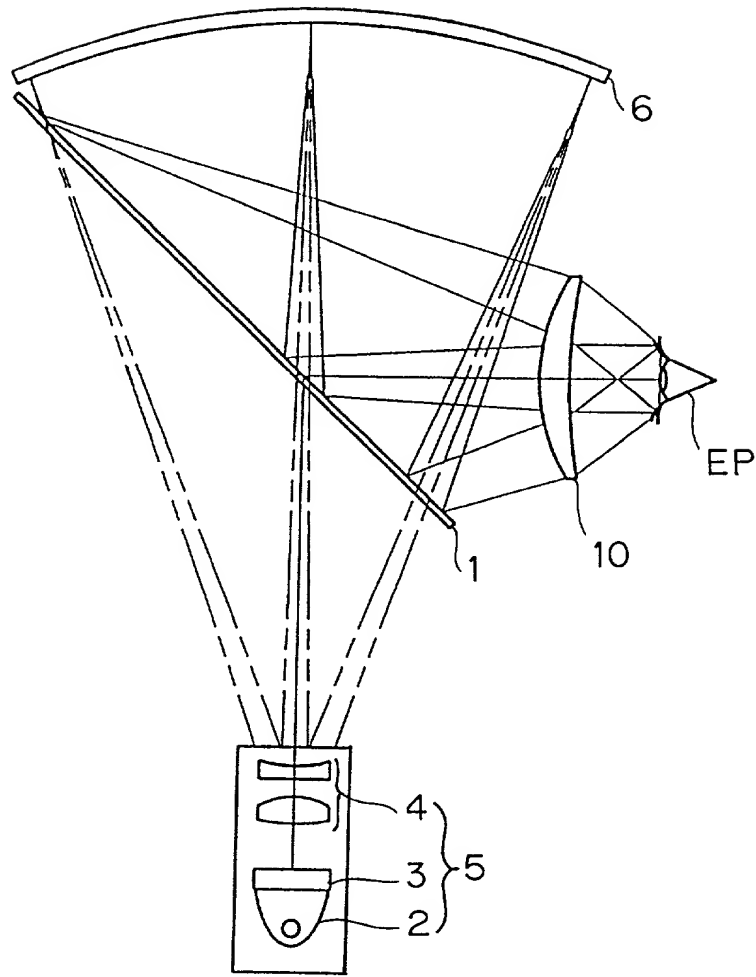
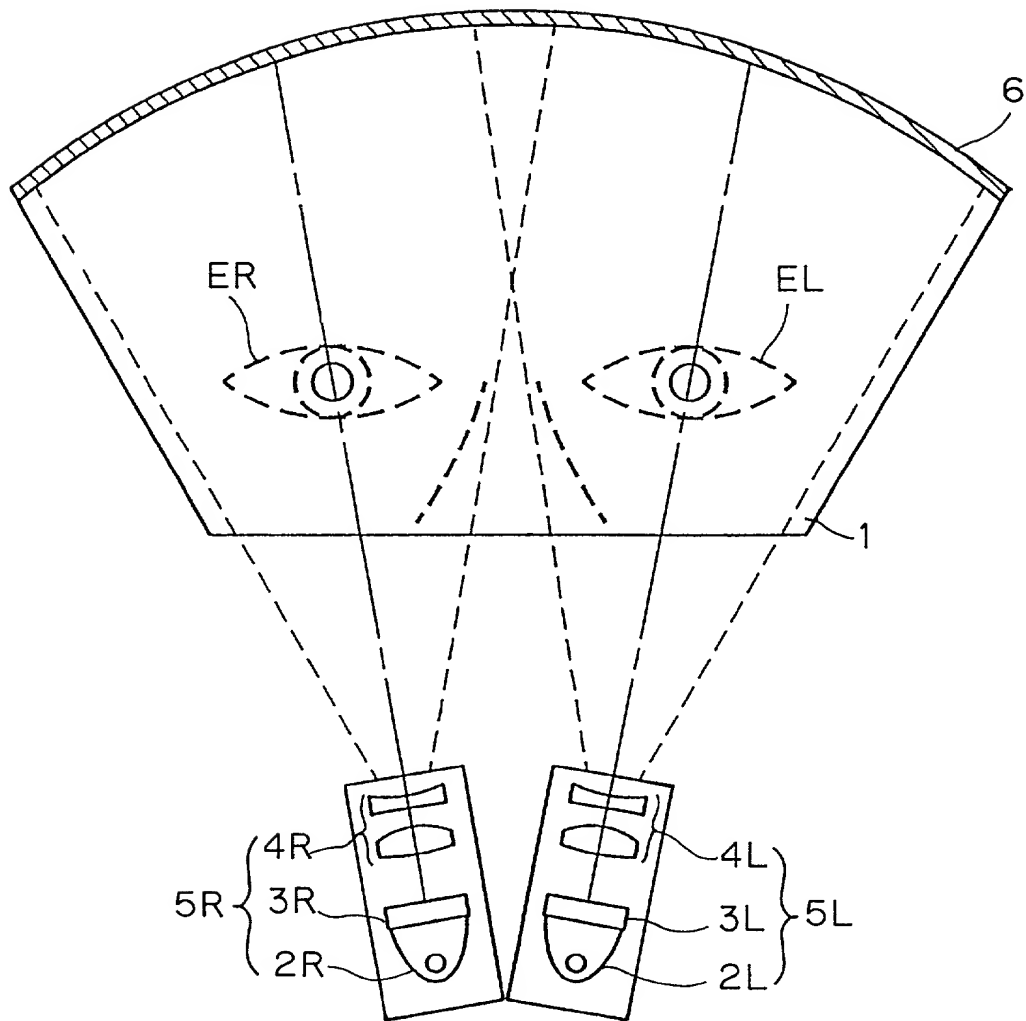




FIG.6



Attorney Docket No. _____

5

DECLARATION AND POWER OF ATTORNEY

FOR PATENT APPLICATION

As a below named inventor, I hereby declare that:

My residence, post office address and citizenship are as stated next to my name.

I believe I am the original, first and sole inventor (if only one name is listed below) or I and the other persons listed below are the original, first and joint inventors (if plural names are listed below) of the subject matter which is claimed and for which a patent is sought on the invention entitled
IMAGE DISPLAY APPARATUS

the specification of which is attached hereto unless the following box is checked:

☐ was filed on _____
as United States Application Number or
PCT International Application Number
_____ and was amended on
_____ (if applicable).

30

I hereby state that I have reviewed and understand the contents of the above identified specification, including the claims, as amended by any amendment referred to above.

5 I acknowledge the duty to disclose information which is material to patentability as defined in Title 37, Code of Federal Regulations, Section 1.56.

10 I hereby claim foreign priority under Title 35, United States Code, Section 119(a)-(d) or 365(b) of any foreign application(s) for patent or inventor's certificate, or 365(a) of any PCT International application which designated at least one country other than the United States, listed below and have also identified below, by checking the box, any foreign application
15 for patent or inventor's certificate, or PCT International application having a filing date before that of the application on which priority is claimed.

20 PRIOR FOREIGN APPLICATION(S)

Priority

Not Claimed

H11-199790 Japan 14/07/1999

(Number) (Country) (Day/Month/Year Filed)

☐

25 _____
(Number) (Country) (Day/Month/Year Filed)

☐

(Number) (Country) (Day/Month/Year Filed)

☐

5

(Number) (Country) (Day/Month/Year Filed)

☐

10

(Number) (Country) (Day/Month/Year Filed)

☐

15 I hereby claim the benefit under Title 35, United States
Code, Section 119(e) of any United States provisional
application(s) listed below.

(Application No.)

(Filing Date)

20

(Application No.)

(Filing Date)

United States Code and that such willful false statements may jeopardize the validity of the application or any patent issued thereon.

5 POWER OF ATTORNEY: As a named inventor, I hereby appoint the following attorney(s) and/or agent(s) to prosecute this application and transact all business in the Patent and Trademark Office connected therewith:

10 John J. Arnott, Reg. No. 39,095
Charles S. Cotropia, Reg. No. 27,189
Kathi A. Cover, Reg. No. 37,803
Daren C. Davis, Reg. No. 38,425
William R. Gustavson, Reg. No. 29,160
15 David L. Hitchcock, Reg. No. 30,067
Kelly J. Kubasta, Reg. No. 44,196
William D. McSpadden, Reg. No. 44,234
Gary A. Ray, Reg. No. 40,313
Steven P. Rhines, Reg. No. 38,595
20 Thomas N. Tarnay, Reg. No. 41,341
James W. Williams, Reg. No. 20,047

25 Send correspondence to:
SIDLEY & AUSTIN
717 North Harwood
Suite 3400
Dallas, Texas 75201-6507

Direct telephone calls to:
James W. Williams
Direct: (214) 981-3328
Main: (214) 981-3300
Attorney Docket No.:

Full name of sole or first inventor

<u>Ichiro</u>	<u>(NMI)</u>	<u>KASAI</u>
First	Middle	Last

5

Inventor's signature: Ichiro Kasai

Date: Jun, 20, 2000

Residence: Kawachinagano-Shi, Osaka, Japan
(city) (prefecture) (country)

10 Citizenship: Japanese

Post Office Address: C/O MINOLTA CO., LTD., Osaka Kokusai Bldg., 3-
13, 2-Chome, Azuchi-Machi, Chuo-Ku, Osaka-Shi, Osaka 541-8556
Japan

15

Full name of second joint inventor, if any

<u>Yasushi</u>	<u>(NMI)</u>	<u>TANIJIRI</u>
First	Middle	Last

20

Inventor's signature: Yasushi Tanijiri

Date: Jun. 12, 2000

Residence: Osakasayama-Shi, Osaka, Japan
(city) (prefecture) (country)

25 Citizenship: Japanese

Post Office Address: C/O MINOLTA CO., LTD., Osaka Kokusai Bldg., 3-
13, 2-Chome, Azuchi-Machi, Chuo-Ku, Osaka-Shi, Osaka 541-8556
Japan

30

[illegible]

Inventor's signature: Hideki Nagata

10 Residence: Kobe-Shi, Hyogo-Ken, Japan
(city) (prefecture) (country)

Post Office Address: C/O MINOLTA CO., LTD., Osaka Kokusai Bldg., 3-
13, 2-Chome, Azuchi-Machi, Chuo-Ku, Osaka-Shi, Osaka 541-8556
15 Japan